BAB

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AGRICULTURAL MEMORANDUM NO 944

Newcastle disease - Part 3 - 1959/60 East Sussex Outbreak (Uckfield)

J Gloster

INTRODUCTION

Gloster (1982a) concluded that studies of past outbreaks of Newcastle disease (ND), would be needed to confirm that airborne transmission of disease can occur in the field. This memorandum examines one of the outbreaks - East Sussex (Uckfield) 1959/60. The outbreak was chosen because:-

1. Disease information was available.

2. A mesogenic* virus strain was involved. This strain caused some mortality, particularly in the younger birds, but was generally associated with mild symptoms and falling egg production levels.

3. Investigations, made at the time of the outbreak, had shown that disease spread by the movement of people, infected materials etc was unlikely in this outbreak (Drummond and Hunnam, 1961).

4. Infection via airborne virus had already been suggested for this outbreak (Drummond and Hunnam, 1961).

ASSUMPTIONS MADE IN THIS STUDY

After discussions with W H Allan, Central Veterinary Laboratory, Ministry of Agriculture, Fisheries and Food (MAFF), Weybridge the following assumptions have been made:-

*Definition given in Gloster (1982a)

ND virus

1. was emitted into the atmosphere by infected birds during this outbreak.

2. emission started 2 days prior to the appearance of the first clinical symptoms.

3. remained airborne for least an hour.

4. remained viable for at least an hour.

5. Infection occurred via the respiratory system.

6. The first reported case was the origin, either directly or indirectly, for disease spread in the area.

7. Meteorological data taken nearly 30km from the outbreak (at Gatwick) were representative of the conditions in the vicinity of the outbreak. The data used in this article are given in Appendix 1.

DISEASE SUMMARY

Disease information used in this paper has been obtained from an article written by Drummond and Hunnam (1961) and from conversations with Hunnam (MAFF-Maidstone) and McDonald (MAFF-Lewis).

During an eight week period in the winter of 1959/60 there was a large epizootic of ND in the Uckfield district of East Sussex. A hundred outbreaks were confirmed within this period.

Figure 1 gives the locations of the first 14 outbreaks and Table 1 the temporal distribution. Full details of each of these 14 outbreaks are given below.

Outbreak 1

This occurred on a pig and poultry farm in the Uckfield district. The owners kept 936 poultry at their Uckfield premises and also had a pig farm at Brighton at which there were no poultry. They collected swill at hotels in Brighton, boiled it at their Brighton farm and took a certain amount of cooked swill to Uckfield for feeding to the pigs kept there. It was not improbable that some unboiled swill could have found its way to Uckfield on the outside of the bins used for transporting the boiled swill, in this way infecting the poultry. No other link with known origins was found.

Symptoms of disease were first seen on 25 December 1959 but the outbreak was not reported until 28 December, having been mistaken for coryza.

Outbreak 2

This outbreak occurred on 28 December in a small flock of three fowls located due north of the first outbreak and about one hundred and twenty yards distant. Disease was reported on 2 January and slaughter completed the same day.

Outbreak 3

The flock involved in this outbreak was a broiler unit of 62,000 chickens. The chickens were kept in eight bays and varied in age from day-old to 10½ weeks old. Six of the bays were accomodated in two big barns of three stories each. Each barn had a single communal ventilation shaft operated by extractor fans. In the middle floor of the second barn, the furthest from the road and the nearest to the valley bottom, disease was first noticed on 1 January. Seventeen chickens died on the first day out of a batch of three thousand 7 week-old chickens. These chickens were separated from others in the bay by wire mesh partitions. The only symptoms noticed were high-pitched cough and drowsiness. Coccidiosis (infection caused by sporoza parasitic in the chicken) was a regular feature of the post-mortem findings but inspissated (coagulated) pus was found in some of the tracheae and airsacs. There

was no evidence of petechiation (pin point hemorrhages) on the serous membranes. 91 chickens died on the second day and 119 on the morning of the third day. Symptoms now noted were the high-pitched cough and drowsiness but in addition, green diarrhoea, mouth breathing, leg and wing paralysis, torticollis (twisted neck) and corneal opacity were in evidence. Throat rattle was not a prominent feature. The chickens on the other side of the wire partition were also beginning to show symptoms. Slaughter of the poultry on this floor was commenced shortly after midday and the whole flock was hand slaughtered by the early hours of 5 January.

Outbreak 4

60 laying pullets, situated in the same lane as Outbreak 1, were involved. First symptoms were noticed on 1 January, disease was confirmed on 3 January and slaughter was completed on 4 January.

Outbreak 5

The fifth outbreak, on a unit of 1023 pullets, was first noticed on 2 January. Confirmation of disease was made on 4 January and slaughter was completed on the same day.

Outbreak 6

This outbreak occurred in a new district several miles to the south. A drop in egg production, from 80 to 70 in a house of 200 layes was noticed on 3 January. Production dropped steadily to 36 on 7 January. There was a total stock of 374 chickens on the premises. Slaughter was not completed until 11 January owing to delays in reporting and obtaining a diagnosis.

Outbreak 7

First symptoms were noticed on 7 January when egg production in a house of 45 pullets dropped from 20 to 0 overnight. There was a total stock of 550 birds on the farm. Disease was confirmed on 9 January.

Outbreak 8

A small holding with 23 chickens was involved. Symptoms were noticed on 9 January and disease confirmation was given on 11 January.

Outbreak 9

This was situated 4½km to the south east of the first outbreak. There were 5558 birds on the premises and when disease was confirmed on 12 January at least 124 birds were ailing.

Outbreak 10

This was adjacent to the previous outbreak. The farm consisted of 21,644 birds. First symptoms were seen on 9 January and disease was confirmed on 12 January. There were at least 80 birds showing visible disease symptoms.

Outbreak 11

14,848 birds, of which 450 were ailing, were involved. Symptoms were first noticed on 10 January and it was confirmed as ND on 13 January.

Outbreak 12

A total of 75 birds were kept on these premises. First symptoms were seen on 11 January and ND was confirmed on 12 January.

Outbreak 13

This was first noticed on 15 January and ND was confirmed on 16 January. 34,478 birds were housed on the premises.

Outbreak 14

A small holding with 4 birds was involved. Disease was confirmed on 17 January.

Reference is made, latter in this article, to a group of outbreaks numbers 16-21 (ON 16-21) which were clustered around ON9 and ON10; these outbreaks were all situated within 2km of ON9 and ON10. Table 2 gives the dates when first symptoms were observed.

METEOROLOGICAL ANALYSIS OF THE OUTBREAKS

The outbreaks been analysed in the following way:-

1. the major virus sources are identified,

2. the period over which airborne virus emission would have occurred is defined,

3. the prevailing winds at the time of virus emission were examined to determine if subsequent outbreaks could have been caused by airborne virus.

Gloster (1982a) when analysing an ND outbreak in Kent limited the period from infection to detection of first symptoms to 4-6 days. That outbreak involved a velogenic* virus strain whose characteristics were reasonably well known. In contrast to this, the outbreak being studied in this article involved a mesogenic* virus strain whose characteristics were not known as precisely. Consequently the following meteorological analysis has been performed over a longer period. It has been assumed that infection could have occurred at anytime from 4-14 days prior to detection of the first clincial symptoms of disease.

Major sources of virus and emission period

Assuming that the quantity of virus released into the atmosphere was proportional to the number of birds affected there would have been high virus excretions from ON1, ON3, ON5, ON9, ON10, ON11 and ON13. An estimate of the number of birds affected and the period over which airborne virus emission would have occurred is given in Table 3.

*Definition in Gloster (1982a)

The maximum virus excretion, in the early stages of the outbreak, is likely to have been from ON3 where thousands of birds were affected.

Airborne disease spread

The number of hours per day, during the 4-14 day period, when the wind would have blown from a virus source towards subsequently confirmed outbreaks were analysed. Tables 4-8 give the results of this analysis.

Virus emission from ON1 - Table 4

With the exception of ON6 virus would have blown over all of the other farms during the period of analysis. ON3-5 and ON7-12 would have been exposed to virus for periods of >3 hours on at least one occasion. Whilst there were no winds measured at Gatwick which were suitable for carriage of virus from ON1 to ON2, because of their proximity to each other it is quite possible that virus would have blown over ON2; a shift in wind direction of 30° to that measured at Gatwick would have been required to give many hours of exposure to virus on 23 or 24 December.

The farm exposed to the longest period of virus exposure was ON3 which would have been downwind of the virus source for a full 24 hour period on 23 December.

Virus emission from ON3 - Table 5

Taking Table 5 in isolation it would appear that there was only a low risk of disease spread to the subsequent outbreaks from virus emitted at ON3. In reality this may have been far from the truth. It must be remembered that the analysis gives the number of hours that the wind was blowing from the source to the recipient birds and does not give an idea of the likely inhaled dosage. ON3, as described earlier, was most likely to have provided the largest source of airborne virus. Consequently even a short exposure period may well have given a considerable dosage to the recipient birds. Simply it may be concluded that ON7, 8, 9, 10, 12 and 13 were potentially infected from virus emitted from this outbreak and that ON12 was most at risk.

Drummond and Hunnam (1961) observed that further disease spread which was reported a week or two later (not included in this study) may well have been attributed to virus emitted from ON3. These outbreaks were situated to the north east of ON3 and the wind was often in this direction during the virus emission period.

Virus emission from ON5 - Table 6

ON5, the smallest of the major virus sources, appears to have played only a small part in further disease spread. The majority of occasions, designated S in Table 6 were when the winds were recorded as calm. Whilst any virus excreted into the atmosphere during these periods would have remained in substantial concentrations it would appear unlikely that this was the source for outbreaks separated from it by up to 6km.

Virus emission from ON9 and ON10 - Table 7

There were several possible occasions when virus could have drifted towards ON12-14. Whilst calm conditions were observed at Gatwick it is quite possible that in the Uckfield area the wind would be light in strength and variable in direction. However as ON9 and 10 were separated from ON12-14 by >5km it would appear unlikely that these outbreaks were caused by airborne virus emitted from these sources.

Reference was made earlier to a group of outbreaks in the immediate vicinity of ON9 and 10 and away from the major part of the outbreaks. See Figure 1. Whilst only limited information about the location and magnitude of the disease was available it is interesting to note that six outbreaks occurred in the space of four days. The most likely sources of virus available for these outbreaks were ON9 and ON10 If infection occurred either through airborne virus, or by some other means when virus levels at ON9 and ON10 were at their height (11 or 12 Jan) an infection period of between 6-10 days would have been involved.

Virus emission from ON11 - Table 8

There were no occasions when virus would have blown from ON11 towards ON13. Whilst virus would have blown, on several occasions from ON11 towards ON14 it would appear more likely, because of its geographical position, that disease was introduced from a much closer source.

Summary of evidence for airborne disease spread

Table 9 sumarises the findings of the previous section. With the exceptions of ON6 and ON14 all of the outbreaks could have been caused by airborne virus emitted from ON1 and ON3.

CHANCE OF INFECTION

Gloster (1982a) concluded that the relationship between chicken population size and likelihood for infection needed examination. It can be shown that for a low inhaled dosage the chance of infection is greatly increased as the sampling population size increases. This effect will be discussed in a future Agricultural Memorandum.

Making the assumption that there were chicken farms and units of all sizes in the Uckfield area and by combing the information from Figure 1 and Table 9 supportive evidence with regard to succeptibility and chicken numbers is obtained from this Outbreak. Figure 2 gives the numbers of birds on each of the farms where ND was confirmed and the distance of these from the appropriate virus sources. It can be seen from this figure that at the larger ranges, where virus concentrations in the atmosphere would have been relatively low, that the only farms which secumbed to the disease were the larger units. At close range both large and small farms were affected.

CONCLUSION

1. The majority of disease spread in this outbreak is consistent with an airborne hypothesis. This analysis has assumed that infection occurred somewhere between 4-14 days prior to the detection of first clinical symptoms. A more precise analysis would have been possible if this "infection-to-symptoms" period had been more accurately known.

2. Infection may have occurred up to 7km from a virus source.

3. Evidence has been presented which supports the hypothesis that at low inhaled dosages of virus a greater chance of infection occurrs when large numbers of susceptible birds are present.

ACKNOWLEDGEMENTS

The author wishes to thank R Hunnam, A McDonald and W H Allan for their invaluable contributions to this study.

REFERENCES

Drummond, D J and Hunnam, R (1961) State Vet. J. 16 No 46, 42.

Gloster, J (1982a) Agricultural Memorandum No 942.

Gloster, J (1982b) Agricultural Memorandum No 943.

Any comments or suggestions on this paper should be referred to the author, Meteorological Office, London Road, Bracknell, Berkshire.

May 1982

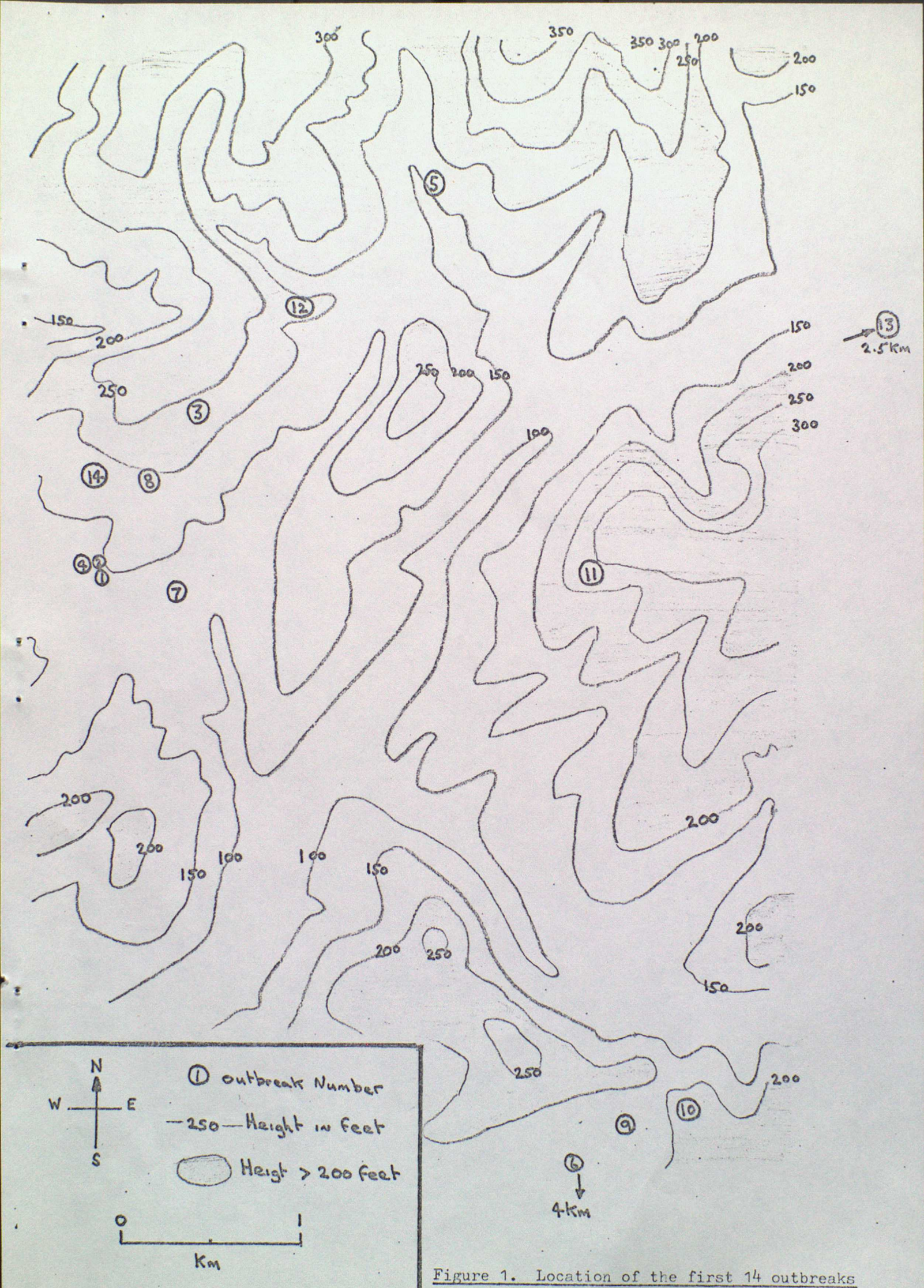
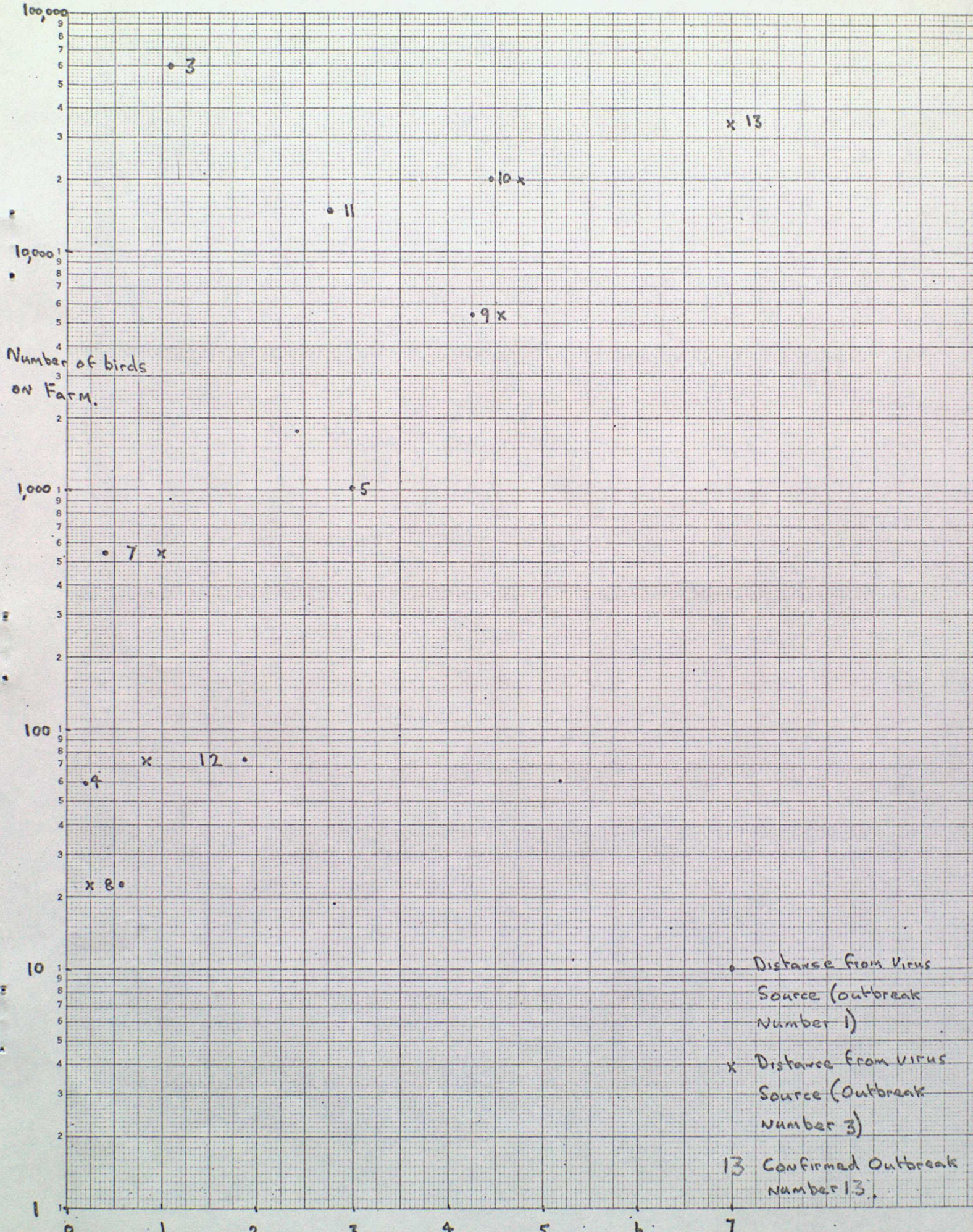


Figure 1. Location of the first 14 outbreaks

Figure 2. The effect of distance from a virus source and the number of birds sampling virus.



OUTBREAK NO	DATE DECEMBER							DATE JANUARY																	
	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	FS			C			S																				
2				FS					C S																		
3								FS		C		S															
4								FS		C	S																
5									FS		C S																
6										FS							C	S									
7														FS		C											
8																FS	C										
9																FS			C								
10																FS			C								
11																	FS			C							
12																		FS	C								
13																						FS	C				
14																								C			

FS = FIRST SYMPTOMS

C = DISEASE CONFIRMED

S = SLAUGHTER

For some outbreaks full disease details were not available

TABLE 1: TEMPORAL DISTRIBUTION OF THE FIRST 14 OUTBREAKS

TABLE 2: DATES WHEN FIRST SYMPTOMS WERE SEEN AT OUTBREAKS 16-21

OUTBREAK NUMBER	FIRST OBSERVED SYMPTOMS
16	17 January
17	18 "
18	18 "
19	19 "
20	19 "
21	20 "

TABLE 3: PERIOD OF VIRUS EMISSION FROM MAJOR VIRUS SOURCES

VIRUS SOURCE (OUTBREAK NUMBER)	NUMBERS OF CHICKENS ON FARM	NUMBER OF CHICKENS WITH CLINICAL SYMPTOMS	ESTIMATED NUMBER EMITTING VIRUS (MAX)	PERIOD OF VIRUS EMISSION
1	936	?	900	23/12* - 31/12
3	62,000	?	Many thousands	30/12 - 5/1+
5	1,023	?	Few thousand	31/12 - 4/1
9	5,558	> 124	Thousands	7/1 - 12/1
10	21,644	> 80	Thousands	7/1 - 12/1
11	14,848	450	Thousands	8/1 - 13/1
13	34,478	?	Thousands	13/1 - 16/1

* 23 December 1959

+ 5 January 1960

? Unknown

TABLE 4: POSSIBILITY OF INFECTION AT OUTBREAK NUMBERS 2-12 FROM VIRUS EMITTED FROM OUTBREAK NUMBER 1 (EMISSION PERIOD 23/12 - 31/12)

DAYS PRIOR TO FIRST SYMPTOMS

OUTBREAK NO	14	13	12	11	10	9	8	7	6	5	4	FIRST SYMPTOMS OBSERVED (DAY 0)
2										S	S	28/12
3						L	S	S	M	M		1/1
4						S	S	M				1/1
5					L	M	L	L	L	S	M	2/1
6												3/1
7					L		M					7/1
8	M	S		S	M +	L						9/1
9			M									9/1
10			M									9/1
11		M +	S	L								10/1
12	S	M	S	L								11/1

L = Long exposure $\geq$ 12 hrs

M = Medium exposure $>$3 hrs and $<$12 hrs

S = Short exposure $\leq$3 hrs, Calm conditions or general direction of drift.

+ = Continuous periods

Analysis period (consistant with virus emission and 4-14 days prior to first symptoms)

TABLE 5: POSSIBILITY OF INFECTION AT OUTBREAK NUMBERS 6-14 FROM VIRUS EMITTED FROM OUTBREAK NUMBER 3 (EMISSION PERIOD 30/12 - 5/1)

DAYS PRIOR TO FIRST SYMPTOMS

OUTBREAK NO	14	13	12	11	10	9	8	7	6	5	4	FIRST SYMPTOMS OBSERVED (DAY 0)
6												3/1
7										S	S	7/1
8								S	S			9/1
9								S	S			9/1
10								S	S			9/1
11												10/1
12			S +	L +	M	S	S	M	S			11/1
13	M	S	S									15/1
14												≙17/1

L = Long exposure ⩾ 12 hrs

M = Medium exposure > 3 hrs and < 12 hrs

S = Short exposure ⩽ 3 hrs, Calm conditions or general direction of drift.

\+ = Continuous periods

Analysis period (consistant with virus emission and 4-14 days prior to first sumptoms)

TABLE 6: POSSIBILITY OF INFECTION AT OUTBREAK NUMBERS 7-14 FROM VIRUS EMITTED FROM OUTBREAK NUMBER 5 (EMISSION PERIOD 31/12 - 4/1)

DAYS PRIOR TO FIRST SYMPTOMS

OUTBREAK NO	14	13	12	11	10	9	8	7	6	5	4	FIRST SYMPTOMS OBSERVED (DAY 0)
7											S	7/1
8								S	S			9/1
9								S*	S			9/1
10								S*	S			9/1
11							S	S	S			10/1
12						S	S					11/1
13	M +	S*	S									15/1
14	S											17/1

L = Long exposure $\geq$ 12 hrs

M = Medium exposure >3 hrs and $<$ 12 hrs

S = Short exposure ≤ 3 hrs, Calm conditions or general direction of drift.

S*= All values of S except for these = Calm Conditions

+ = Continuous periods

☐ Analysis period (consistant with virus emission and 4-14 days prior to first symptoms.

TABLE 7: POSSIBILITY OF INFECTION AT OUTBREAK NUMBERS 12-14 FROM VIRUS EMITTED FROM OUTBREAK NUMBERS 9-10 (EMISSION PERIOD 7/1 - 12/1)

DAYS PRIOR TO FIRST SYMPTOMS

OUTBREAK NO	14	13	12	11	10	9	8	7	6	5	4	FIRST SYMPTOMS OBSERVED (DAY 0)
12											S	11/1
13							S					15/1
14					S							17/1

L = Long exposure $\geq$ 12 hrs

M = Medium exposure $>$ 3 hrs and $<$ 12 hrs

S = Calm conditions

+ = Continuous periods

☐ Analysis period (consistant with virus emission and 4-14 days prior to first symptoms.

TABLE 8: POSSIBILITY OF INFECTION AT OUTBREAK NUMBERS 13-14 FROM VIRUS EMITTED FROM OUTBREAK NUMBER 11 (EMISSION PERIOD 8/1 - 13/1)

DAYS PRIOR TO FIRST SYMPTOMS

OUTBREAK NO	14	13	12	11	10	9	8	7	6	5	4	FIRST SYMPTOMS OBSERVED (DAY 0)
13												15/1
14							S	S			L	17/1

L = Long exposure $\geq$ 12 hrs

M = Medium exposure $>$3 hrs and $<$ 12 hrs

S = Short exposure $\leq$3 hrs, Calm conditions or general direction of drift.

+ = Continuous periods

☐ Analysis period (consistant with virus emission and 4-14 days prior to first symptoms.

TABLE 9: SUMMARY OF THE RESULTS PRESENTED IN TABLES 4-8

OUTBREAK NO.	VIRUS SOURCE (OUTBREAK NUMBER) 1	3	5	9/10	11
2	✓				
3	✓				
4	✓				
5	✓				
6					
7	✓	✓			
8	✓	✓			
9	✓	✓			
10	✓	✓			
11	✓				
12	✓	✓			
13		✓			
14					

HOURLY: 10MIN WIND DIRN. ; 10MIN WIND SPEED ; PRESENT WEATHER ; PAST WEATHER AT LONDON/GATWICK AIRPORT (5271)
UNITS: DEGS. KNOTS CODE CODE FOR DECEMBER 1959

DY	HR	DIRN.	SPEED	PR WR	PA WR	DY	HR	DIRN.	SPEED	PR WR	PA WR	DY	HR
19	18	230	15	59	6	26	0	220	18	25	6		
19	21	250	15	2	6	26	3	230	23	3	1		
20	0	220	15	2	6	26	6	250	13	29	9		
20	3	220	18	60	6	26	9	240	22	25	8		
20	6	210	25	58	6	26	12	230	19	80	9		
20	9	200	25	59	6	26	15	220	16	80	8		
20	12	220	24	61	6	26	18	240	14	29	9		
20	15	230	28	1	6	26	21	230	15	1	8		
20	18	220	14	1	0	27	0	240	20	1	8		
20	21	230	17	2	0	27	3	240	26	2	8		
21	0	240	12	2	0	27	6	230	21	3	8		
21	3	220	7	2	0	27	9	230	12	81	8		
21	6	200	7	3	0	27	12	230	17	81	8		
21	9	230	5	2	0	27	15	220	21	27	8		
21	12	0	0	2	1	27	18	230	14	25	8		
21	15	250	7	2	2	27	21	250	9	1	1		
21	18	240	4	2	1	28	0	230	15	2	1		
21	21	190	5	2	0	28	3	240	21	81	8		
22	0	210	4	10	0	28	6	300	16	25	8		
22	3	0	0	10	0	28	9	270	10	1	1		
22	6	0	0	66	6	28	12	280	15	2	1		
22	9	190	5	21	8	28	15	290	15	25	8		
22	12	200	17	1	8	28	18	300	15	2	8		
22	15	180	20	65	6	28	21	270	11	2	1		
22	18	240	20	21	6	29	0	260	10	2	1		
22	21	220	11	1	6	29	3	240	6	3	1		
23	0	210	10	2	8	29	6	250	6	3	2		
23	3	220	16	80	8	29	9	0	0	2	2		
23	6	220	11	25	8	29	12	190	14	61	6		
23	9	210	9	25	8	29	15	170	15	61	6		
23	12	220	13	2	8	29	18	230	10	20	6		
23	15	210	11	80	8	29	21	220	12	21	6		
23	18	220	11	25	8	30	0	240	14	50	6		
23	21	210	7	2	8	30	3	250	19	1	5		
24	0	200	8	2	8	30	6	270	14	2	5		
24	3	160	7	3	1	30	9	260	7	2	1		
24	6	230	10	81	8	30	12	270	11	2	1		
24	9	150	6	1	8	30	15	260	6	3	2		
24	12	150	3	3	8	30	18	280	6	1	2		
24	15	240	6	3	1	30	21	210	10	3	2		
24	18	230	12	2	1	31	0	220	13	50	5		
24	21	230	9	80	8	31	3	220	12	20	5		
25	0	260	12	3	8	31	6	220	13	2	5		
25	3	250	12	3	1	31	9	210	13	2	5		
25	6	250	8	2	1	31	12	200	13	51	5		
25	9	170	3	3	1	31	15	180	10	51	5		
25	12	190	14	2	1	31	18	190	13	10	5		
25	15	170	19	63	6	31	21	210	16	60	5		
25	18	220	19	21	6								
25	21	230	25	1	6								

Appendix 1 — Meteorological observations used in this study

HOURLY: AMOUNT LOW CLOUD ; RELATIVE HUMIDITY
UNITS: OKTAS PER.C

AT LONDON/GATWICK AIRPORT (5271)
FOR DECEMBER 1959

DY	HR	A.LOW	R.H.
1	0	3	100
1	3	2	97
1	6	0	100
1	9	9	98
1	12	7	98
1	15	1	96
1	18	9	100
1	21	9	100
2	0	9	98
2	3	9	98
2	6	9	99
2	9	9	99
2	12	7	96
2	15	4	80
2	18	8	90
2	21	2	94
3	0	0	97
3	3	0	94
3	6	8	97
3	9	5	94
3	12	5	85
3	15	8	93
3	18	8	94
3	21	8	87
4	0	1	85
4	3	7	80
4	6	8	84
4	9	1	80
4	12	1	67
4	15	3	70
4	18	3	74
4	21	1	75
5	0	0	82
5	3	0	89
5	6	0	92
5	9	1	96
5	12	0	77
5	15	0	74
5	18	2	86
5	21	8	84
6	0	8	95
6	3	8	95
6	6	8	94
6	9	8	91
6	12	8	92
6	15	8	92
6	18	8	97
6	21	8	94
7	0	8	93
7	3	8	93
7	6	8	93
7	9	8	93
7	12	8	90
7	15	8	92
7	18	6	89
7	21	7	79
8	0	7	79
8	3	8	78
8	6	8	78
8	9	7	90
8	12	7	83
8	15	7	78
8	18	8	77
8	21	8	89
9	0	2	96
9	3	0	96
9	6	0	97
9	9	1	98
9	12	6	84
9	15	3	84
9	18	8	85
9	21	7	86
10	0	8	91
10	3	5	81
10	6	2	83
10	9	1	82
10	12	8	92
10	15	8	89
10	18	8	93
10	21	8	82
11	0	8	91
11	3	8	89
11	6	8	89
11	9	8	92
11	12	8	87
11	15	8	83
11	18	8	80
11	21	8	80
12	0	8	80
12	3	8	79
12	6	8	94
12	9	8	94
12	12	8	92
12	15	8	90
12	18	8	87
12	21	7	87
13	0	3	93
13	3	0	96
13	6	9	96
13	9	0	97
13	12	6	100
13	15	8	96
13	18	8	99
13	21	8	97
14	0	8	96
14	3	8	96
14	6	8	95
14	9	8	95
14	12	8	92
14	15	8	90
14	18	8	91
14	21	8	92
15	0	7	91
15	3	8	94
15	6	8	94
15	9	8	93
15	12	8	92
15	15	3	96
15	18	0	100
15	21	0	100
16	0	3	100
16	3	3	91
16	6	6	88
16	9	8	92
16	12	8	96
16	15	7	93
16	18	8	93
16	21	7	90
17	0	7	87
17	3	8	93
17	6	8	96
17	9	8	94
17	12	7	89
17	15	4	78
17	18	0	77
17	21	1	77
18	0	1	84
18	3	0	84
18	6	3	83
18	9	7	82
18	12	6	77
18	15	6	65
18	18	0	67
18	21	0	78
19	0	0	89
19	3	0	90
19	6	0	91
19	9	8	91
19	12	8	92
19	15	8	97
19	18	8	95
19	21	7	91
20	0	8	88
20	3	8	88
20	6	8	92
20	9	8	98
20	12	7	83
20	15	1	69
20	18	0	66
20	21	0	73
21	0	0	77
21	3	0	89
21	6	0	92
21	9	1	96
21	12	1	78
21	15	1	69
21	18	0	95
21	21	0	96
22	0	0	92
22	3	0	97
22	6	7	93
22	9	6	84
22	12	2	85
22	15	8	92
22	18	8	93
22	21	1	89
23	0	1	90
23	3	3	89
23	6	1	87
23	9	6	89
23	12	1	85
23	15	6	88
23	18	1	85
23	21	1	89
24	0	0	91
24	3	2	92
24	6	8	95
24	9	3	93
24	12	7	84
24	15	6	83
24	18	1	96
24	21	8	93
25	0	7	89
25	3	1	91
25	6	0	93
25	9	1	97
25	12	2	82
25	15	8	94
25	18	6	94
25	21	4	81
26	0	5	88
26	3	0	81
26	6	7	97
26	9	5	75
26	12	6	80
26	15	8	90
26	18	2	97
26	21	2	82
27	0	0	76
27	3	2	72
27	6	4	75
27	9	6	82
27	12	8	91
27	15	7	78
27	18	7	90
27	21	0	82
28	0	0	82
28	3	7	89
28	6	2	75
28	9	6	80
28	12	6	72
28	15	7	84
28	18	5	73
28	21	6	75
29	0	0	83
29	3	0	82
29	6	1	93
29	9	4	94
29	12	8	93
29	15	8	95
29	18	8	100
29	21	8	93
30	0	8	86
30	3	1	89
30	6	0	81
30	9	0	82
30	12	0	76
30	15	5	77
30	18	2	86
30	21	8	86
31	0	8	99
31	3	8	94
31	6	8	90
31	9	8	88
31	12	8	94
31	15	8	98
31	18	8	92
31	21	8	93

Appendix 1 - Meteorological observations used in this study

HOURLY: TOTAL CLOUD AMT. ; TYPE LOW CLOUD ; TYPE MED. CLOUD ; TYPE HIGH CLOUD AT LONDON/GATWICK AIRPORT (5271)
UNITS: OKTAS CODE CODE CODE FOR DECEMBER 1959

DY	HR	TOTAL	LOW	MED.	HIGH
19	18	8	7	-32768	-32768
19	21	7	5	-32768	-32768
20	0	8	7	-32768	-32768
20	3	8	7	-32768	-32768
20	6	8	5	-32768	-32768
20	9	8	7	-32768	-32768
20	12	7	5	-32768	-32768
20	15	1	1	3	0
20	18	0	0	0	0
20	21	0	0	0	0
21	0	0	0	0	0
21	3	1	0	0	2
21	6	2	0	0	2
21	9	4	2	3	3
21	12	7	2	3	3
21	15	7	1	3	1
21	18	4	1	0	1
21	21	3	0	0	1
22	0	0	0	0	0
22	3	1	0	3	0
22	6	7	5	-32768	9
22	9	7	8	3	-32768
22	12	7	1	3	8
22	15	8	5	2	-32768
22	18	8	5	2	-32768
22	21	2	5	3	-32768
23	0	3	1	0	1
23	3	7	3	0	2
23	6	7	9	0	2
23	9	7	9	3	-32768
23	12	7	4	0	3
23	15	6	9	0	3
23	18	6	2	0	2
23	21	1	5	0	3
24	0	2	0	0	2
24	3	6	9	0	3
24	6	8	9	-32768	-32768
24	9	3	9	0	0
24	12	7	5	-32768	-32768
24	15	6	5	-32768	-32768
24	18	1	5	0	0
24	21	8	8	-32768	-32768
25	0	7	5	-32768	-32768
25	3	1	5	0	0
25	6	0	0	0	0
25	9	7	9	0	9
25	12	8	6	7	7
25	15	8	7	2	-32768
25	18	6	5	0	0
25	21	4	5	0	0

DY	HR	TOTAL	LOW	MED.	HIGH
26	0	5	9	0	0
26	3	7	0	0	2
26	6	7	9	-32768	-32768
26	9	6	9	3	2
26	12	7	3	3	2
26	15	8	3	-32768	-32768
26	18	2	9	0	0
26	21	2	2	0	0
27	0	3	0	0	1
27	3	2	1	0	0
27	6	4	1	0	0
27	9	7	3	6	-32768
27	12	8	9	-32768	-32768
27	15	7	9	0	8
27	18	7	7	1	-32768
27	21	0	0	0	0
28	0	0	0	0	0
28	3	7	3	-32768	-32768
28	6	2	2	0	0
28	9	6	5	3	0
28	12	7	7	3	0
28	15	7	8	-32768	-32768
28	18	5	5	0	2
28	21	7	5	0	2
29	0	4	0	0	2
29	3	7	0	2	5
29	6	8	5	2	7
29	9	8	5	2	-32768
29	12	8	7	2	-32768
29	15	8	6	-32768	-32768
29	18	8	7	-32768	-32768
29	21	8	6	2	-32768
30	0	8	5	-32768	-32768
30	3	3	5	0	1
30	6	0	0	0	0
30	9	7	0	0	1
30	12	7	0	3	1
30	15	7	5	3	5
30	18	5	5	3	1
30	21	8	5	-32768	-32768
31	0	8	5	-32768	-32768
31	3	8	5	-32768	-32768
31	6	8	6	-32768	-32768
31	9	8	6	-32768	-32768
31	12	8	6	-32768	-32768
31	15	8	7	-32768	-32768
31	18	8	5	-32768	-32768
31	21	8	5	-32768	-32768

DY HR

Appendix 1 - Meteorological observations used in this study

HOURLY: 10MIN WIND DIRN. ; 10MIN WIND SPEED ; PRESENT WEATHER ; PAST WEATHER AT LONDON/GATWICK AIRPORT (5271)
UNITS: DEGS. KNOTS CODE CODE FOR JANUARY 1960

DY	HR	DIRN.	SPEED	PR WR	PA WR
1	0	220	16	21	6
1	3	210	20	20	6
1	6	200	22	63	6
1	9	220	17	21	6
1	12	260	14	2	6
1	15	260	15	2	6
1	18	240	7	1	6
1	21	270	3	1	1
2	0	260	4	2	1
2	3	0	0	2	1
2	6	80	4	20	5
2	9	0	0	63	6
2	12	80	8	21	6
2	15	360	4	51	6
2	18	0	0	51	6
2	21	0	0	10	5
3	0	290	1	46	5
3	3	0	0	43	4
3	6	0	0	28	5
3	9	0	0	28	5
3	12	200	3	10	5
3	15	210	3	10	2
3	18	200	5	21	6
3	21	190	7	10	6
4	0	190	12	51	6
4	3	200	13	45	5
4	6	0	0	10	5
4	9	180	1	50	4
4	12	210	6	51	5
4	15	200	6	20	5
4	18	220	8	51	5
4	21	210	7	10	5
5	0	220	10	2	5
5	3	210	7	1	1
5	6	220	13	51	5
5	9	240	6	20	6
5	12	340	11	2	1
5	15	300	7	1	1
5	18	310	7	5	0
5	21	280	6	5	0
6	0	290	5	10	0
6	3	0	0	10	0
6	6	280	2	10	0
6	9	180	2	11	0
6	12	330	5	10	0
6	15	310	3	5	0
6	18	0	0	10	0
6	21	0	0	49	0
7	0	0	0	49	0
7	3	0	0	49	4
7	6	0	0	49	4
7	9	0	0	45	4
7	12	40	4	42	4
7	15	0	0	44	4
7	18	0	0	42	4
7	21	0	0	44	4
8	0	0	0	47	4
8	3	330	1	45	4
8	6	10	4	43	4
8	9	330	5	47	4
8	12	320	5	43	4
8	15	350	5	44	4
8	18	340	5	28	4
8	21	20	6	10	1
9	0	30	9	50	1
9	3	80	4	3	5
9	6	0	0	2	5
9	9	80	16	2	1
9	12	100	14	26	8
9	15	60	7	85	8
9	18	40	10	85	8
9	21	60	11	35	8
10	0	60	6	26	8
10	3	50	12	85	8
10	6	60	10	86	8
10	9	90	6	86	8
10	12	40	8	85	8
10	15	40	4	1	8
10	18	350	7	4	8
10	21	350	4	2	8
11	0	340	6	22	7
11	3	340	6	22	7
11	6	330	7	68	7
11	9	340	8	61	7
11	12	340	9	21	7
11	15	10	10	80	5
11	18	30	12	25	8
11	21	340	4	10	1
12	0	250	3	71	7
12	3	340	8	22	7
12	6	30	17	25	8
12	9	360	7	2	0
12	12	310	5	4	1
12	15	340	7	4	1
12	18	330	2	10	1
12	21	340	2	10	2
13	0	0	0	10	1
13	3	0	0	10	1
13	6	0	0	70	7
13	9	100	3	71	7
13	12	100	8	71	7
13	15	100	8	71	7
13	18	90	13	1	7
13	21	70	7	3	1
14	0	0	0	3	1
14	3	0	0	2	8
14	6	20	3	10	8
14	9	340	8	73	8
14	12	360	11	22	8
14	15	20	17	71	7
14	18	10	15	71	7
14	21	20	17	71	7
15	0	30	16	22	7
15	3	30	15	85	8
15	6	50	15	1	8
15	9	30	11	1	1
15	12	40	11	3	0
15	15	20	8	2	1
15	18	20	7	5	1
15	21	360	7	4	2
16	0	350	6	4	2
16	3	350	6	4	2
16	6	0	0	4	2
16	9	320	7	4	2
16	12	300	6	5	2
16	15	330	9	4	2
16	18	330	8	10	2
16	21	340	9	10	2
17	0	290	4	21	6
17	3	340	9	2	2
17	6	350	7	2	2
17	9	290	4	2	1
17	12	240	8	2	1
17	15	250	7	2	1
17	18	270	7	60	6
17	21	270	8	10	6
18	0	270	8	2	6
18	3	220	5	2	2
18	6	230	9	2	2
18	9	240	11	2	2
18	12	250	14	2	2
18	15	250	16	2	8
18	18	220	11	2	8
18	21	210	7	1	1
19	0	230	7	2	1
19	3	220	7	3	1
19	6	200	7	1	2
19	9	210	16	60	2
19	12	220	18	61	6
19	15	220	15	2	6

Appendix 1 - Meteorological observations used in this study

HOURLY: AMOUNT LOW CLOUD ; RELATIVE HUMIDITY AT LONDON/GATWICK AIRPORT (5271)
UNITS: OKTAS PER.C FOR JANUARY 1960

DY	HR	A.LOW	R.H.
1	0	3	88
1	3	8	86
1	6	8	89
1	9	8	96
1	12	8	90
1	15	7	85
1	18	3	83
1	21	1	86
2	0	3	91
2	3	8	95
2	6	8	94
2	9	8	99
2	12	8	99
2	15	8	99
2	18	8	97
2	21	8	97
3	0	8	98
3	3	9	99
3	6	8	97
3	9	8	99
3	12	8	95
3	15	8	92
3	18	8	96
3	21	8	93
4	0	8	97
4	3	9	99
4	6	8	99
4	9	8	99
4	12	8	98
4	15	8	99
4	18	8	99
4	21	8	96
5	0	8	91
5	3	8	90
5	6	8	94
5	9	7	97
5	12	8	79
5	15	1	76
5	18	1	74
5	21	0	79
6	0	0	85
6	3	0	86
6	6	0	91
6	9	0	95
6	12	0	82
6	15	0	77
6	18	0	97
6	21	0	96
7	0	0	96
7	3	9	98
7	6	9	97
7	9	9	98
7	12	0	98
7	15	0	98
7	18	0	94
7	21	0	96
8	0	9	98
8	3	9	99
8	6	9	99
8	9	9	99
8	12	9	97
8	15	8	98
8	18	8	96
8	21	3	88
9	0	7	90
9	3	2	93
9	6	1	98
9	9	7	73
9	12	6	76
9	15	6	96
9	18	7	85
9	21	7	89
10	0	7	83
10	3	7	85
10	6	8	87
10	9	8	87
10	12	7	90
10	15	1	80
10	18	7	71
10	21	1	78
11	0	6	85
11	3	8	93
11	6	8	95
11	9	8	93
11	12	8	92
11	15	7	89
11	18	8	91
11	21	5	84
12	0	8	95
12	3	8	95
12	6	7	85
12	9	1	86
12	12	8	77
12	15	4	64
12	18	3	82
12	21	7	88
13	0	1	88
13	3	5	93
13	6	8	95
13	9	8	96
13	12	8	90
13	15	8	90
13	18	0	73
13	21	4	79
14	0	5	78
14	3	7	83
14	6	6	89
14	9	8	92
14	12	2	78
14	15	7	80
14	18	6	81
14	21	7	89
15	0	7	78
15	3	8	87
15	6	4	68
15	9	3	76
15	12	1	74
15	15	5	67
15	18	7	77
15	21	8	81
16	0	8	83
16	3	4	92
16	6	7	82
16	9	7	86
16	12	3	77
16	15	5	86
16	18	8	82
16	21	8	85
17	0	7	92
17	3	7	88
17	6	8	85
17	9	6	89
17	12	1	66
17	15	7	79
17	18	8	94
17	21	7	97
18	0	0	93
18	3	6	98
18	6	1	99
18	9	0	98
18	12	4	84
18	15	6	77
18	18	7	85
18	21	0	93
19	0	0	94
19	3	0	98
19	6	1	98
19	9	6	93
19	12	7	97
19	15	5	86
19	18	8	91
19	21	8	71
20	0	0	82
20	3	0	73
20	6	0	76
20	9	0	69
20	12	0	64
20	15	0	7
20	18	8	82
20	21	8	87
21	0	8	97
21	3	8	100
21	6	8	95
21	9	8	96
21	12	8	94
21	15	8	95
21	18	8	94
21	21	8	89
22	0	8	92
22	3	8	92
22	6	8	96
22	9	8	91
22	12	5	86
22	15	8	91
22	18	8	73
22	21	8	83
23	0	8	91
23	3	8	94
23	6	8	94
23	9	8	96
23	12	8	94
23	15	8	93
23	18	8	89
23	21	8	93
24	0	8	93
24	3	7	94
24	6	8	97
24	9	7	86
24	12	8	86
24	15	8	92
24	18	8	91
24	21	8	85
25	0	0	93
25	3	0	96
25	6	0	98
25	9	1	98
25	12	2	81
25	15	2	78
25	18	2	92
25	21	0	98
26	0	9	98
26	3	9	98
26	6	9	98
26	9	9	97
26	12	0	97
26	15	9	100
26	18	9	100
26	21	8	98
27	0	9	98
27	3	8	98
27	6	8	99
27	9	8	98
27	12	8	96
27	15	8	93
27	18	8	97
27	21	8	97
28	0	8	97
28	3	8	98
28	6	8	93
28	9	8	91
28	12	8	93
28	15	8	88
28	18	8	87
28	21	8	79
29	0	7	79
29	3	3	82
29	6	0	87
29	9	0	88
29	12	1	88
29	15	2	85
29	18	0	82
29	21	8	89
30	0	8	91
30	3	8	91
30	6	7	93
30	9	7	93
30	12	3	84
30	15	4	82
30	18	2	85
30	21	6	88
31	0	6	88
31	3	6	90
31	6	9	92
31	9	12	88
31	12	15	89
31	15	18	92
31	18	21	92
31	21		

Appendix 1 - Meteorological observations used in this study

DATE OF PRINTOUT: 3/11/1981

HOURLY: TOTAL CLOUD AMT. ; TYPE LOW CLOUD ; TYPE MED. CLOUD ; TYPE HIGH CLOUD AT LONDON/GATWICK AIRPORT (5271)
UNITS: OKTAS CODE CODE CODE FOR JANUARY 1960

DY	HR	TOTAL	LOW	MED.	HIGH
1	0	8	5	-32768	-32768
1	3	8	6	-32768	-32768
1	6	8	7	2	-32768
1	9	8	5	-32768	-32768
1	12	8	8	-32768	-32768
1	15	7	8	-32768	-32768
1	18	3	5	0	0
1	21	1	5	0	0
2	0	3	5	0	0
2	3	8	5	-32768	-32768
2	6	8	5	-32768	-32768
2	9	8	7	-32768	-32768
2	12	8	7	-32768	-32768
2	15	8	7	-32768	-32768
2	18	8	6	-32768	-32768
2	21	8	6	-32768	-32768
3	0	8	6	-32768	-32768
3	3	9	-32768	-32768	-32768
3	6	8	6	-32768	-32768
3	9	8	6	-32768	-32768
3	12	8	5	-32768	-32768
3	15	8	5	-32768	-32768
3	18	8	5	-32768	-32768
3	21	8	5	2	-32768
4	0	8	7	-32768	-32768
4	3	9	-32768	-32768	-32768
4	6	8	6	-32768	-32768
4	9	8	6	-32768	-32768
4	12	8	6	-32768	-32768
4	15	8	6	-32768	-32768
4	18	8	6	-32768	-32768
4	21	8	5	-32768	-32768
5	0	8	5	-32768	-32768
5	3	3	5	0	0
5	6	8	6	-32768	-32768
5	9	7	5	-32768	-32768
5	12	8	5	-32768	-32768
5	15	1	1	3	0
5	18	1	1	0	0
5	21	1	0	0	0
6	0	1	0	0	1
6	3	1	0	0	0
6	6	1	0	0	0
6	9	1	0	0	0
6	12	3	0	0	1
6	15	3	0	0	1
6	18	2	0	0	1
6	21	1	0	0	0
7	0	9	-32768	-32768	-32768
7	3	9	-32768	-32768	-32768
7	6	9	-32768	-32768	-32768
7	9	9	-32768	-32768	-32768
7	12	7	0	8	8
7	15	8	0	7	-32768
7	18	8	0	3	-32768
7	21	3	0	3	0
8	0	9	-32768	-32768	-32768
8	3	9	-32768	-32768	-32768
8	6	9	-32768	-32768	-32768
8	9	9	-32768	-32768	-32768
8	12	9	-32768	-32768	-32768
8	15	8	6	-32768	-32768
8	18	8	6	-32768	-32768
8	21	3	6	0	0
9	0	7	5	-32768	-32768
9	3	2	5	0	0
9	6	1	5	0	0
9	9	7	8	-32768	-32768
9	12	6	8	-32768	-32768
9	15	7	8	-32768	-32768
9	18	7	8	-32768	-32768
9	21	7	8	-32768	-32768
10	0	7	8	-32768	-32768
10	3	7	5	-32768	-32768
10	6	8	8	-32768	-32768
10	9	8	7	-32768	-32768
10	12	7	7	-32768	-32768
10	15	1	8	3	0
10	18	7	5	-32768	-32768
10	21	7	5	3	-32768
11	0	8	5	1	-32768
11	3	8	7	-32768	-32768
11	6	8	7	-32768	-32768
11	9	8	5	-32768	-32768
11	12	8	5	-32768	-32768
11	15	7	8	-32768	-32768
11	18	8	8	-32768	-32768
11	21	5	8	0	0
12	0	8	2	2	-32768
12	3	8	8	-32768	-32768
12	6	7	8	-32768	-32768
12	9	1	8	0	0
12	12	8	8	-32768	-32768
12	15	4	5	0	0
12	18	3	5	0	0
12	21	7	5	0	0
13	0	1	5	0	0
13	3	8	5	3	-32768
13	6	8	5	-32768	-32768
13	9	8	7	-32768	-32768
13	12	8	0	2	-32768
13	15	8	0	2	-32768
13	18	7	0	7	-32768
13	21	4	5	0	0
14	0	5	5	0	0
14	3	7	5	-32768	-32768
14	6	8	5	-32768	-32768
14	9	8	7	2	-32768
14	12	8	5	0	-32768
14	15	8	5	2	-32768
14	18	7	5	1	-32768
14	21	7	5	1	-32768
15	0	7	2	-32768	-32768
15	3	8	8	-32768	-32768
15	6	4	5	0	0
15	9	3	5	0	0
15	12	1	5	0	0
15	15	5	8	3	0
15	18	7	5	0	0
15	21	8	5	-32768	-32768
16	0	8	5	-32768	-32768
16	3	7	5	3	-32768
16	6	8	5	0	7
16	9	8	5	3	-32768
16	12	8	5	2	-32768
16	15	7	5	3	-32768
16	18	8	5	-32768	-32768
16	21	8	5	-32768	-32768
17	0	7	6	0	0
17	3	7	5	0	0
17	6	8	5	-32768	-32768
17	9	6	5	-32768	-32768
17	12	1	5	0	0
17	15	7	5	-32768	-32768
17	18	8	5	-32768	-32768
17	21	7	5	-32768	-32768
18	0	7	0	5	2
18	3	8	5	3	-32768
18	6	5	5	0	1
18	9	7	0	3	2
18	12	7	8	3	2
18	15	6	8	-32768	-32768
18	18	7	5	-32768	-32768
18	21	7	0	0	0
19	0	7	0	3	0
19	3	8	0	3	2
19	6	7	0	0	2
19	9	8	6	7	-32768
19	12	8	7	7	-32768
19	15	7	8	0	0

Appendix 1 - Meteorological observations used in this study